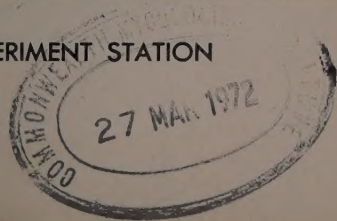


New Flash-Flame Soil Pasteurizer

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New Flash-Flame Soil Pasteurizer

by *A. G. Newhall and W. T. Schroeder*

The application of heat has long been recognized as one of the best methods of ridding soil of injurious microorganisms, weed seeds, and insect pests which bother the vegetable grower, nurseryman, plant grower, florist, and forester. Many of these growers have no ready supply of steam, hot water, or even electricity, although they are sometimes able to use one of the available soil fumigants, such as chloropicrin or methyl bromide.¹ In the Northern States particularly, at the season of the year when growers have the time to make soil treatments, it may be impossible for some of them to use fumigants because the soil temperature is too low.

How Pasteurizer Operates

For those who want to eliminate damping-off, weed seeds, nematodes, insects, and wilt-producing organisms from their potting soils, seedbeds, compost piles, and plant-house benches, the oil-burning, continuous type flash-flame pasteurizer herein described may be a welcome piece of equipment. It can be used any time of year as long as the soil is not frozen. It can be moved easily, either on its own two wheels or in a pick-up truck, since it weighs approximately only 600 pounds. It operates on white kerosene or light fuel oil and burns but five or six gallons an hour, at a cost of less than a dollar. It is possible to pasteurize about 2 cubic yards of soil an hour, with one man shoveling it in and another hauling it away as fast as it is heated (2 cubic yards = 54 cubic feet = 43 bushels = approximately 130 flats or boxes).

As illustrated in figure 1, the pasteurizer is an adaptation of a mobile aggregate heater employed by road repairmen in the colder months to heat the materials used in the asphalt patching of surfaced roads. It consists of a heated, slightly sloping steel cylinder, or drum, hexagonal in cross-section, 8 feet long and 20 inches in diameter, which revolves about 40 times a minute. Soil shoveled into the upper end is tumbled against the hot sides of this drum and in a few seconds is brought to pasteurizing temperature and drops from the lower end in a steady stream. The necessary heat is supplied by a blow torch mounted near the outlet, with its flame directed into the lower end of the cylinder against the direction of the movement of the soil. The torch is a demountable separate unit and comes in various sizes from 2.5 gallons to 6 gallons an hour in fuel-burning capacity. The drum is turned by a 1½ horsepower gasoline engine, which also activates the fuel pump to keep the requisite pressure of

¹See Cornell University Agricultural Experiment Station Buls. 850 (for a detailed description of the uses of soil fumigants) and 731 (for electric devices for pasteurizing soils).



Figure 1. General view of flash-flame soil pasteurizer, with blow torch in operation.

30 to 35 pounds on the blow torch. All the above, plus fuel tank, are mounted on a frame over two wheels and two retractable legs which serve to give the proper pitch to the rotating drum.

Final maximum temperature of the soil as it drops from the drum into waiting flats, boxes, bushel baskets, wheelbarrow, or traveling belt is determined by several factors, among which are (1) the original soil temperature; (2) its moisture content; (3) the slope of the drum, which determines how long the soil remains in it; (4) the rate of shoveling or delivery into the cylinder; and (5) the size and operation of the blow torch. All but the first one or two factors are subject to rather easy manipulation. Even the soil moisture can be altered, at least in one direction. It is when one alters more than one factor at a time that difficulties may arise. As with learning to drive any new piece of equipment, a little practice is needed to achieve perfection.

Regulation of final soil temperature important

The old idea that the soil must be heated to 212°F and held there from $\frac{1}{2}$ to 2 hours for satisfactory sterilization has been completely exploded, not only by the work done with this equipment but by the hundreds of tests made at the Cornell University Experiment Stations at Ithaca and Geneva, with electric soil pasteurizers in the years between 1934 and 1941.² In the experiments reported herein a final soil temperature

²For discussion of electric soil disinfection consult Cornell Extension Bul. 217.

of 170–190°F was found satisfactory, but 160°F or lower was not (see figure 2, lower). It might be pointed out that milk is commonly pasteurized at 160–162°F, but milk is held for 15 seconds after it attains this temperature. In the soil pasteurizer the end temperature is reached only a few seconds or instants before the soil leaves the drum, and it begins to cool immediately thereafter. Also the plant grower is interested in killing many spore-forming microorganisms, while the dairyman is not. Therefore, final temperatures of 175–190°F are recommended. This may be especially important in cold or windy weather when the soil tends to cool quickly.

Organic matter not burned out of the soil

Devotees of “organic gardening” and growers who put a high value on organic content of potting soil are at first horrified at the thought of subjecting soil to a flame with a temperature of 1700 to 2000°F. Soil moisture is the safety factor and the key to the preservation of the organic matter. As long as there is moisture in the soil its temperature will not go much above 212°F. To prove this, on numerous occasions bits of newspaper have been incorporated with soil and put through the pasteurizer. They invariably came through without being scorched unless the soil was rather dry to begin with. Pieces of straw, rotted manure, and clumps of grass and muck soil have been similarly exposed with like results, provided that the soil was slightly moist to begin with. A good seedbed moisture content seems to be about right. Soil in this condition at the start is a little drier at the end of the process but its organic content seems not to have been impaired. In this connection it might be pointed out that for the past 50 or 60 years throughout the Southern States and in Italy it has been a common practice, and still is, to sterilize tobacco seedbeds before sowing, by burning for several hours, brush and timber piled 3 feet high on the soil. This disinfests the beds to a depth of 3 or more inches, and insures a healthier root system.³ In India, blow torches have been used for the same purpose.

In two of the experiments, a very rich compost or sandy loam, too dry to begin with, was slightly affected to the detriment of rapid growth of cucumber and melon, which are very sensitive to an excess of ammonia, but the effect was transient and was not noticeable on snapdragon, sweet pea, stock, beet, spinach, or garden peas growing in the same flats with these two cucurbits. (See note under figure 3.)

Experiments on Control of Damping-off and Weed Seeds at Ithaca

Several comparisons of the emergence of a number of flower and vegetable seedlings in heated and unheated soils have been conducted in com-

³See *Tobacco Diseases and Their Control*, (U. S. Dept. Agr., Farmers Bul. 2023, Nov. 1950).

Table 1. Control of pre-emergence damping-off by flash-flame pasteurizing (Soil temperature 180°F)

	No. seeds sown	Seedlings emerged	
		Check	Treated
Weeds.....	...	70	0
Snapdragon....	250	10	115
Stock.....	100	7	51
Beets.....	75	5	109
Cucumber.....	33	24	33
Sweet pea.....	45	18	34
	503	64	342

post soils from different locations in the State. In the first of these, a final soil temperature of 180°F was obtained with a local soil used in vegetable growing. The resulting stand of seedlings grown in flats of treated and untreated soil are given in table 1 and are shown in figure 2, upper.

The control of weeds was excellent, but clover was not prevalent in this soil.

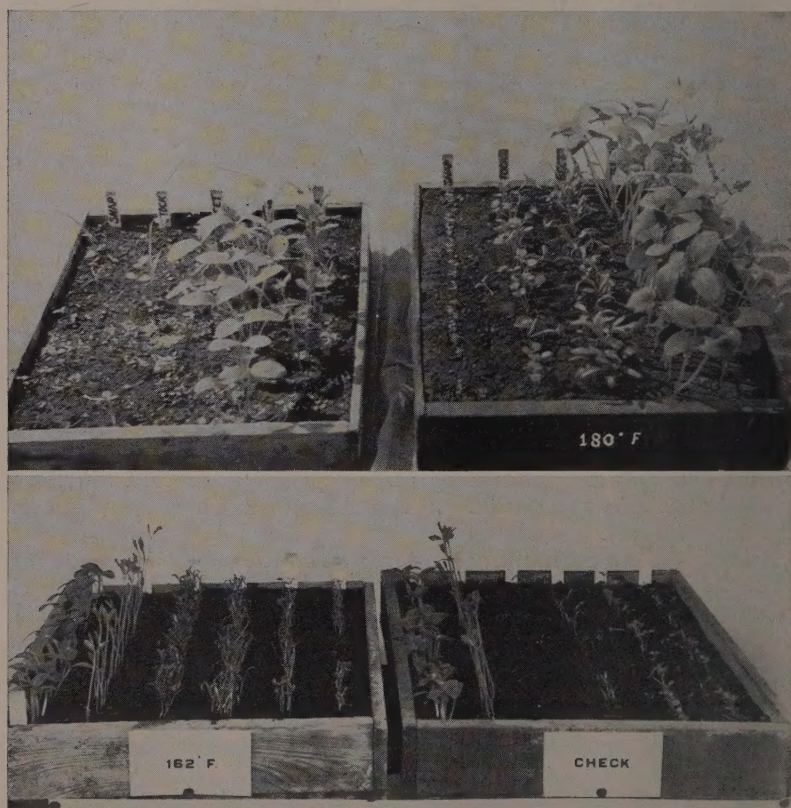


Figure 2. Effect of pasteurizing soil, infested with damping-off organisms, on emergence and stand of flowers and vegetables. **Upper left:** soil untreated; **upper right:** flash-pasteurized at 180° F. **Lower:** muck soil insufficiently heated to 162° F, showing some damping-off in one row; despite this, however, it was better than the untreated soil (70 per cent vs. 30 per cent stand).

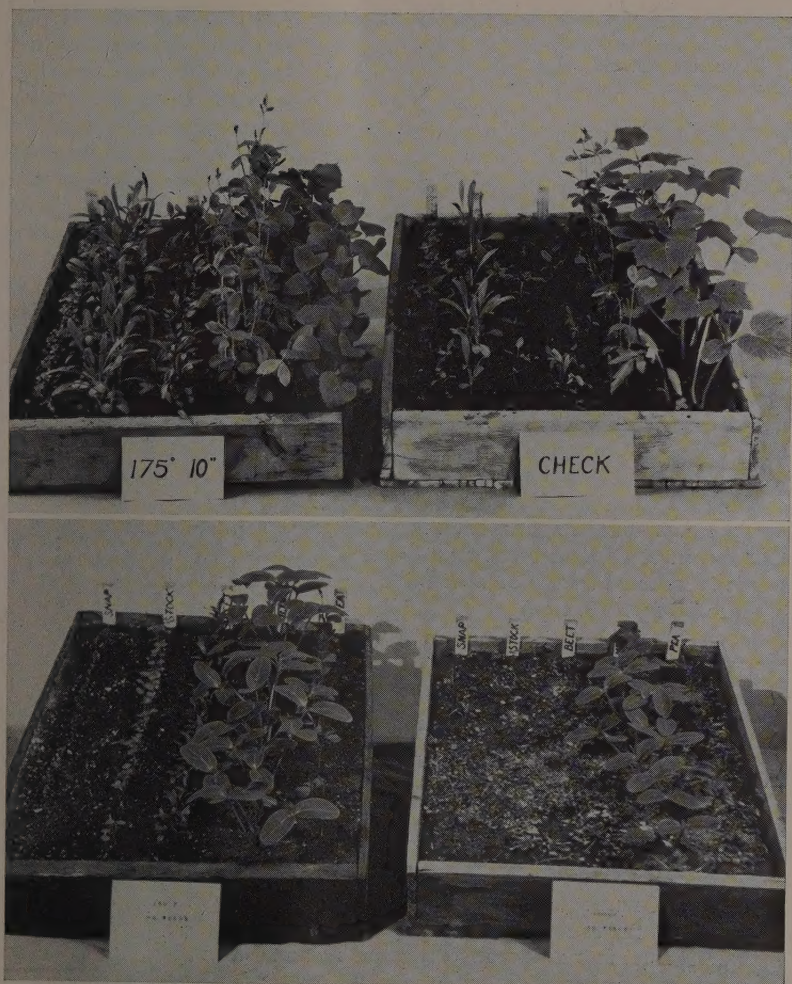


Figure 3. Control of damping-off. **Left:** pasteurized soil samples; **right:** untreated. Soil from two sources reacted in a similar manner, except that melon grew faster in untreated upper soil (see page 5 and table 3).

In another test, two compost soils from the Rochester and Buffalo areas (Wise and Agle) were compared before and after being pasteurized. In this experiment the treated soils were unfortunately placed in old un-

Table 2. Damping-off control from flash-flame pasteurization
(Rochester soil, 190°, and Buffalo soil, 170°F)

	Seeds sown	Plants emerged			
		Rochester check	Rochester heated	Buffalo check	Buffalo heated
Weeds.....	...	60	0	77	26
Snapdragon...	350	56	72	127	132
Centaurea....	100	1	80	11	83*
Beets.....	70	0	30*	14	75
Sweet pea.....	50	5	24	21	41
Cucumber....	30	7	17	15	29
	500	69	223	188	356

*Postemergence damping-off claimed several of these.

area (see table 2).

In a test made with a local gravelly sand used by the Department of Vegetable Crops at Cornell University, soil was heated to 175°F and allowed to cool slowly in a metal bushel basket for 6 hours before being placed in flats. Good control of damping-off and of weeds is indicated by the data in table 3. (See also figure 3, top.)

sterilized flats. After emerging, some of the seedlings damped-off very rapidly, probably because of recontamination. This can be a serious problem if due precaution is not taken to give old containers an adequate treatment before using again. Weed control was good, but a few clover seeds endured the treatment in the soil from the Buffalo

Table 3. Damping-off control from flash-flame pasteurization at 175°F

	Seeds sown	Seedlings emerged	
		Check	Pasteurized
Weeds.....	...	44	3*
Snapdragon...	250	39	141
Stocks.....	100	28	20
Beets.....	75	20	83
Melons.....	33	23	31
Peas.....	40	4	39
	498	114	314

*All three were clover.

Damping-off Control Experiments at Geneva

Heated soil is slow to cool. Therefore pasteurized soil was held in bushel containers for 1, 2, and 5 hours before being spread out to cool, to take advantage of any "fireless cooker" effect this storage period might achieve. Five barrels of soil from as many locations in western New York were brought to Geneva in October. These were selected because they were suspected of harboring, in one case, *Phytophthora parasitica*, the cause of a foot and stem rot of tomato; in another, *Verticillium albo-atrum*, cause of a wilt of tomato and many other crops; and in another, several common root rotting organisms such as *Rhizoctonia*, *Ascochyta*, *Fusarium*, and *Alternaria*.

All samples were brought to a final temperature of 170° ± 2°F. As the first bushel of soil of each sample was pasteurized it was set aside for 5 hours, the second for 2 hours, and the third for 1 hour. The fourth was quickly carried to the greenhouse and spread out in a half-inch layer on paper. A fifth, the check, was not pasteurized. At the end of the 1, 2, and 5 hour periods, the other 1-bushel samples were spread out to cool in like manner, and on the following day 4 replicate pots of each were sown with

100 seeds each of tomatoes, stock, and eggplant. Counts were made of the total seedlings emerging, the amount of postemergence damping-off, the number with healthy and diseased roots, and the number of weeds in each of the pots. The results are set forth in tables 4-7.

From the standpoint of pre-emergence damping-off it may be seen from table 4 that no improvement in original stand of seedlings was obtained by the after-heating storage of the pasteurized soil for 1 or 5 hours before cooling down. Neither was there any difference among the after-heating storage treatments with respect to postemergence damping-off (table 5). Furthermore, the data in table 6 show that the number of healthy roots on these seedlings was as high in the soils cooled quickly as in those held for a 5-hour "fireless cook." The striking effect of pasteurizing heavily contaminated soil, with immediate cooling, on emergence and damping-off is illustrated in figure 4.

It would appear from these data that the "fireless cook" was unnecessary, and that flame-pasteurized soil can be cooled and safely planted immediately after treatment. Shredding, pasteurizing, cooling, and sowing can all take place the same day if a grower has no place to store pasteurized soil. However it would probably be desirable to store pasteurized soil while still hot if possible, for it is conceivable that some soils may harbor infected roots, stems, or sclerotia of fungi which might not be completely sterilized in the short exposure period (see page 16).



Figure 4. Effect of pasteurizing (170° F) soil infested with damping-off organisms. **Left:** untreated soil; **right:** soil heated and cooled immediately. **Top center:** tomato; **lower left:** eggplant; **lower right:** stock.

Table 4. Percentage emergence of stock, tomato, and eggplant grown in 5 different soils
(Heated to 170°F and held warm for various periods, Geneva, 1950)*

Cooperators submitting soil samples	Stock					Tomato					Eggplant				
	Storage period					Storage period					Storage period				
	Not heated	5 hours	1 hour	5 minutes	Soil average	Not heated	5 hours	1 hour	5 minutes	Soil average	Not heated	5 hours	1 hour	5 minutes	Soil average
Conti.....	40	86	88	85	75	81	95	92	96	91	32	54	60	57	51
Russo.....	10	90	89	87	69	45	96	96	98	84	23	67	67	64	54
Canning Crops Farm.....	54	80	86	85	76	91	96	94	90	93	24	66	60	60	56
Quaker Maid Co.....	19	83	81	85	67	48	94	98	96	84	35	67	67	63	58
Notaro.....	22	80	82	86	68	83	97	97	96	93	32	60	59	56	52
Temperature treatment average	29	84	85	86		70	96	95	95		32	62	63	60	

*Highly significant difference between heated and nonheated soils, except with tomato in Canning Crops Farm (Geneva Experiment Station) soil; no significant difference between storage periods.

Table 5. Percentage of postemergence damping-off of stock, tomato, and eggplant seeded in 5 different soils
(Pasteurized at 170°F and held warm for various periods, Geneva, 1950)*

Cooperators submitting soil samples	Stock					Tomato					Eggplant				
	Storage period					Storage period					Storage period				
	Not heated	5 hours	1 hour	5 minutes	Soil average	Not heated	5 hours	1 hour	5 minutes	Soil average	Not heated	5 hours	1 hour	5 minutes	Soil average
Conti.....	71	0	0	0	18	71	0	2	0	18	17	0	0	0	4
Russo.....	73	8	0	0	20	78	0	0	0	20	35	0	0	0	9
Canning Crops Farm.....	23	1	0	0	5	20	0	0	0	5	1	0	0	0	0
Quaker Maid Co.....	47	0	9	0	14	36	0	0	0	9	1	0	0	0	0
Notaro.....	36	0	0	0	9	45	0	0	0	11	8	0	0	0	2
Temperature treatment average	49	2	2	0		50	0	0	0		12	0	0	0	

*Percentage based on total number of plants emerged. Highly significant difference between heated and nonheated soil; no significant difference among storage periods; highly significant differences among soils.

Table 6. Percentage of healthy roots of stock, tomato, and eggplant seeded in 5 different soils (Pasteurized at 170°F and held warm for various periods, Geneva, 1950)*

Cooperators submitting soil samples	Stock						Tomato						Eggplant					
	Storage period						Storage period						Storage period					
	Not heated	5 hours	1 hour	5 minutes	Soil average		Not heated	5 hours	1 hour	5 minutes	Soil average		Not heated	5 hours	1 hour	5 minutes	Soil average	
Conti.....	2	86	87	83	64		0	93	91	96	70		16	54	60	57	47	
Russo.....	2	75	89	87	63		0	96	94	96	72		10	63	67	63	51	
Canning Crops Farm.....	9	78	84	84	64		7	94	90	88	70		16	66	57	60	50	
Quaker Maid Co.....	4	82	67	84	59		2	93	98	96	72		20	66	67	62	54	
Notaro.....	2	80	81	83	62		10	96	96	94	74		19	60	58	55	48	
Temperature treatment average	4	80	82	84			4	94	96	94			16	62	62	59		

*Highly significant difference between heated and nonheated soil; no significant difference among storage periods.

Control of *Phytophthora* Foot-rot and *Verticillium* Wilt in Compost Soil

The danger of certain field diseases developing in tomato plants grown in the compost soils used by large plant growers has been recognized for years. With some diseases, such as the *Alternaria* or early blight collar rot, this has been adequately taken care of by a fungicide spray schedule; with others, particularly the *Phytophthora* foot-rot, this method has not always been successful. Another one, *Verticillium* wilt, cannot be controlled successfully except by soil treatment, either by heat or soil fumigants.

In one test, soil known to be infested with the causal organism of *Phytophthora* foot-rot was heated to 170°F. Some of the soil was cooled immediately and some stored for 1, 2, and 5 hours before cooling. Healthy tomato plants were pricked into these soils as well as into nonheated soil from the same batch. The elimination of the pathogen from the heated soil was indicated by the fact that none of the plants grown in it, regardless of after-heating storage treatment of the soil, showed any symptoms of the disease; whereas many developed symptoms and died in the non-heated soil, as shown in figures 5 and 6. In another test, two batches of similarly infested soil were heated, one to 180°F, the other to 220°F. Six pots of each of these two soils and six of the nonheated soil were pricked with healthy plants, which were allowed to grow until they reached trans-

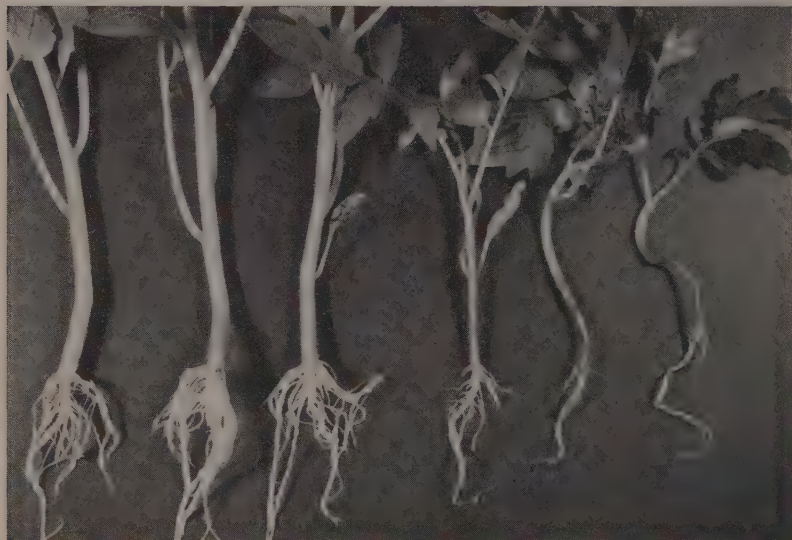


Figure 5. Control of *Phytophthora* foot rot by pasteurization (170° F). Three tomato plants at left grown in pasteurized soil; those at right in *Phytophthora*-infested non-pasteurized soil.

planting size. Foot rot developed readily in the nonheated soil, but none developed in the heated soils except in two of the six pots of the soil heated to 180° F (table 7). Although it is possible that the soil in these



Figure 6. Control of *Phytophthora* foot-rot by pasteurization (170° F). Upper: tomatoes started in and pricked out into pasteurized soil. Lower: healthy plants pricked into untreated soil known to be harboring *Phytophthora*.

Table 7. Control of *Phytophthora* foot-rot of tomato by pasteurizing infested soil at two temperatures

(Geneva, 1950)

Pasteurizing treatment	Number of plants out of 20 showing <i>Phytophthora</i> foot-rot lesions					
	A	B	C	D	E	F
Heated to 180°F..	7*	0	0	11*	0	0
Heated to 220°F..	0	0	0	0	0	0
None.....	15	19	10	17	17	20

*More likely the result of contamination by spattering water from check pots than of insufficient pasteurization.

ing pasteurized soil in dirty containers or near sources of contamination.

The fungus causing *Verticillium* wilt of tomato is often suspected of being present in plant-growing beds, but it is difficult to prove since symptoms of the disease seldom show until after the plants have been transplanted to the field. The effectiveness of the flash-flame pasteurization of wilt-infested soil is indicated by the fact that no disease appeared on plants grown in soil heated to 170°F, regardless of whether the soil was stored 1, 2, or 5 hours before cooling. Neither could the causal organism be recovered from such plants. But plants grown in the same soil not pasteurized developed typical symptoms of the disease, and the organism was recovered from them (figure 7).

The adequacy of the pasteurization in eliminating *Verticillium* wilt of eggplant was confirmed in another experiment in which one-third of a batch of infested soil was heated to 180°F, one-third to 220°, and the remainder was untreated. No symptoms developed in either of the pasteurized portions, whereas eggplants growing in the nonheated soil were visibly affected by the disease, especially if they were allowed to grow for a considerable period of time (as indicated in figure 8).

Control of Weed Seeds

From table 8, in which are presented the results of tests with 12 soils heated to temperatures between 170° and 190°F, it is evident that the common weed seeds of field and compost soils are usually killed by pasteurization at these temperatures. Two exceptions are certain legumes and mallows. These are well known to have long-lived seeds. Interesting work by Professor Muenscher, of the Cornell University Department of Botany, has shown that instantaneous dipping of 62-year-old seeds of *Abutilon theophrasti* for only 3 seconds in boiling water increased their germination from 6 per cent to 42 per cent. Since this is possibly the very mallow found in our soils, and since some of the clovers such as *Trifolium* and *Melilotus* are very likely to react in the same way, it seems reasonable to conclude that, while most seeds are killed, those of at least two families

two pots was not pasteurized completely, the development of the disease is more likely to have resulted from contamination arising from the pots of nonheated soil that were intermingled on the greenhouse bench with those containing the heated soil. This condition emphasizes the necessity of being careful to avoid plac-



Figure 7. Control of Verticillium wilt of tomato by pasteurization (170° F). Three plants at left grown in pasteurized soil; three at right grown in wilt-infested non-pasteurized soil. Lowest leaflets are turning yellow on third plant from right.



Figure 8. Control of Verticillium wilt of eggplant by soil pasteurization (180° F). Plant at left grown in pasteurized soil; plant at right, grown in nonheated soil, shows severe symptoms.

may be stimulated to germinate by such brief soil pasteurization. Fortunately they are among our least troublesome ones.

Control of Three Sclerotia-forming Fungi

To make sure that the sclerotia, or resting bodies, of fungi are also killed in the brief time that the soil is in the pasteurizer, 25 small envelopes made of wire screening, about 1 inch square, were loaded with a few sclerotia of the following fungi previously grown in pure culture for 6 weeks on potato dextrose agar: *Sclerotinia sclerotiorum*, *Sclerotium rolfsii*⁴, and *Rhizoctonia solani*. These were put through the pasteurizer while soil was being treated, and brought to the laboratory, where 15 of

Table 8. Summary of weed seed control in 12 different soils flame-pasteurized (Geneva and Ithaca, 1950)

Cooperators submitting soil samples	Temperature, °F	Hours storage before cooling	No. weeds per 4 pots*			Total
			Legume	Mallow	Others†	
Conti (compost)	170	5	3	4	2	9
	170	1	9	6	1	16
	170	0	5	1	2	8
	0	0	0	1	21	22
Russo (compost)	170	5	9	3	0	12
	170	1	20	1	1	22
	170	0	16	0	2	18
	0	0	0	0	16	16
Canning Crops Farm (field soil)	170	5	0	8	0	8
	170	1	0	11	1	12
	170	0	0	0	0	0
	0	0	0	2	152	154
Notaro (field soil)	170	5	1	0	0	1
	170	1	1	0	0	1
	170	0	1	0	0	1
	0	0	0	0	13	13
Quaker Maid Co. (compost)	170	5	3	1	0	4
	170	1	0	0	0	0
	170	0	1	1	0	2
	0	0	0	1	12	13
Agles (compost)	170	0	25	..	2	27
	0	0	1	..	53	54
Steffen (compost)	180	0	7	..	1	8
	0	0	1	..	40	41
Rinn (compost)	170	0	9	..	0	9
	0	0	0	..	27	27
Department of Vegetable Crops, Ithaca (gravelly sand)	180	0	3	..	0	3
	0	0	0	..	44	44
Wise (compost)	190	0	0	..	0	0
	0	0	0	..	60	60
Department of Plant Pathology, Ithaca: Field soil	180	6	0	..	0	0
	0	6	0	..	70	70
	162	0	3	..	0	3
	0	0	1	..	27	28

*Each pot 64 square inches in area. Single flats of 290 sq. in. used in all but first 5 locations.

†Other weeds include grasses, purslane, pigweed, chickweed, etc.

⁴Growing on steamed barley. Culture from Dr. P. A. Young of Jacksonville, Texas.

each kind were plated out on potato dextrose agar. Though bacterial growth occurred, not one of 45 sclerotia was viable. All of the untreated checks grew promptly. It is concluded that this type of flash pasteurization, when properly conducted, is as effective against small sclerotia as against the oospores of *Pythium* or chlamydospores of *Fusarium* and *Verticillium* or conidia of these and other pathogenic fungi. Larger sclerotia, however, may need higher temperatures or an after-treatment storage period: in another trial with 46 very dry sclerotia of *S. sclerotiorum* ranging up to an inch in diameter, 23 of them, all over $\frac{1}{4}$ inch, survived treatment with a final temperature of 165°F. In this trial 25 other medium-sized sclerotia not in wire envelopes were all killed.

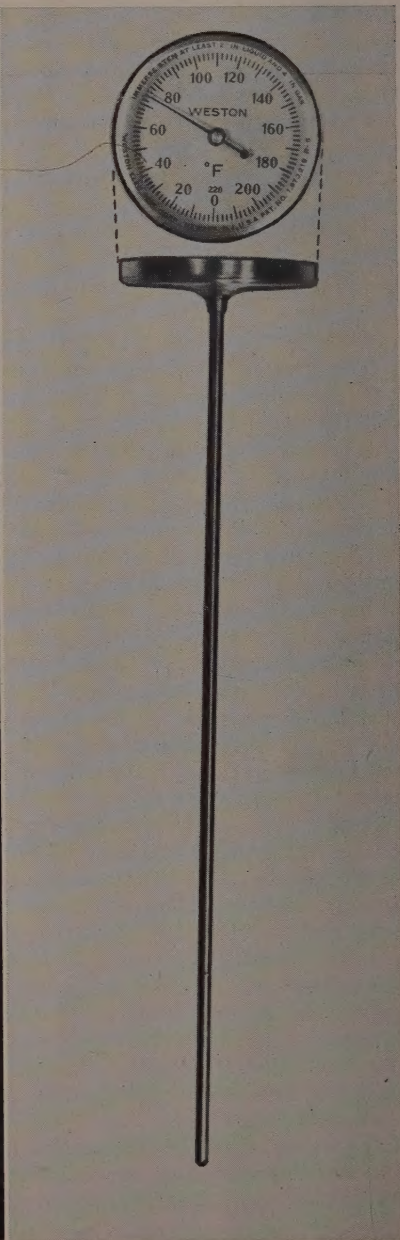
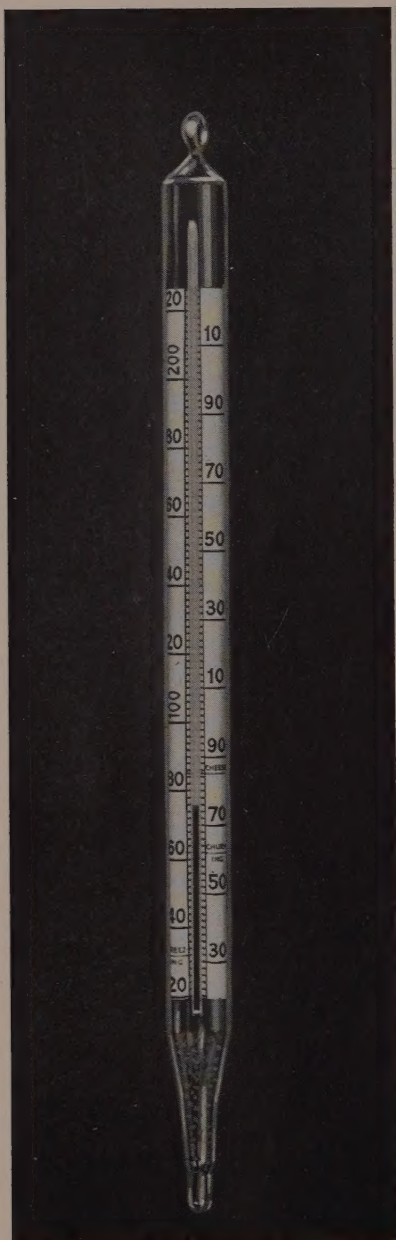
Discussion

The process of soil pasteurization here pictured is novel not because heat is applied directly to the soil with a flame. As pointed out earlier, this has been done before. It is novel because of the short time of exposure, low final temperatures advocated, continuity of the process, and low fuel cost.

All microorganisms have thermal death points which are lower in the presence of moisture than in dry air. It is therefore essential that the soil have enough moisture so that none of the organisms contained will be dry. On the other hand any excess moisture is sure to reduce final temperature, because it takes roughly three times as many heat units to raise a pound of water as to raise a pound of dry soil one degree. So too much water is undesirable. It is particularly undesirable if there is much clay present, since clay tends to encourage pelleting of the soil into balls, and sticking to the insides of the drum.

A thermometer should always be at hand and should be used on the soil as it comes through and piles up in whatever receptacle is provided to receive it. One found satisfactory is a mercury-filled, floating type dairy thermometer, used in creameries and cheese factories (see figure 9). It is reasonably strong for a glass instrument, is quickly read, and not very expensive. The kind with a colored fluid is cheaper, but slower-reacting and not so accurate. One of the authors bought one at a country hardware store and found that it registered nearly 10° off. It should be tested for accuracy within the range of its intended use. This is important because soil heated only to 160°F has repeatedly been shown to be inadequately treated. An all-metal thermometer (figure 9) is recommended to eliminate breakage, even though it is more expensive. Growers should aim for a soil temperature of 175–190°F. This will be easier to achieve in August than in March, with soil on the dry side rather than on the wet, and in a quiet sheltered spot.

Management of the blowtorch to get the highest efficiency deserves a few words. Pressure on the fuel line should be maintained at the point recommended by the manufacturer. In firing up remember that the tray



beneath the coil, to hold starting fuel, is large enough to meet the needs of very cold windy weather. So at all other times fill it only one-fourth full, and thus reduce unnecessary carbon accumulation. If the coil becomes fouled with carbon black, which is a good insulator, it may result in too low a coil temperature. This will give a yellow flame of lower heat content. Clean the coils occasionally with a brush to remove excess carbon. The flow of fuel to the torch must be carefully regulated, for if too fast it will flood the coils and cool them, resulting in a yellow flame which may go out. Watch the color of the flame and regulate the fuel valve carefully in accordance with its color. One-fourth to one-half turn of the needle valve is enough.

The use of gasoline as a coil-warming fuel does not eliminate the formation of carbon on the coil, and since it also introduces explosion hazards it is not recommended.

The blow torch is mounted in a nonrigid manner to permit being turned to the side when no soil is being treated. This is to prevent overheating of the drum, which is made of metal that could expand with heat to the point of not fitting its rollers. A good deal of the heat imparted to the soil comes from its rolling and tumbling against the hot sides of the drum. If the drum is too hot, the first one or two cubic feet of soil to come through may also be overheated. On the other hand, in wintry weather it may be wise to shield the drum from cold winds to preserve its heat. A little practice and close watch of the soil temperature will be rewarding.

Pasteurized soil should never be returned to dirty benches, bins, or flats. Flats and benches can be dipped or swabbed with formaldehyde 1 to 50 or a 1 per cent copper sulfate or carbolic acid solution if plants are growing near by. Tools can be flamed with the torch. Many florists have taken to the admirable practice of dipping all lumber in a copper naphthenate solution such as "cuprinol" before building flats or benches. This is a good fungicide and wood preservative, and, though initially more expensive, makes flats last longer than do any of the above treatments.

← **Figure 9. Left:** a quickly read, mercury, floating, dairy thermometer, with limits just below freezing and above boiling, is well suited to soil pasteurizing work. **Right:** an all-metal dial type is much more durable.

